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ABSTRACT

The theoretical and practice-based framework is presented for a study that explored the effect of teachers' use of alternative assessment on their mathematics teaching. A model for the impact of alternative assessment on teacher knowledge and classroom teaching processes is proposed, building on work by E. Fennema and M. L. Franke (1992) and P. L. Peterson (1988). A research study to test the model is described, including a description of the coursework provided and a discussion of the methodology and data sources. Subjects were 17 female teachers and 1 male teacher (4 African Americans and 14 Whites) in grades 4 through 10. In addition to data from observations of teachers, results from informal data are presented, including class notes, teacher-made tests, and summaries written by the teachers describing assessment strategies. These data, along with those from observations and student reports, provide evidence that knowledge and use of alternative assessments did help mathematics teachers change their teaching strategies to reflect approaches shown by research to result in higher order thinking. One table gives a sample course syllabus, and one figure illustrates teacher concepts. (Author/SLD)

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A Theory of Classroom Assessment and Teacher Practice in Mathematics

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ABSRACT

This paper presents the theoretical and practice-based framework for a study which explored the effect of teachers' use of alternative assessment on their mathematics teaching. A model for the impact of alternative assessment on teacher knowledge and classroom teaching processes is proposed, building on work by Fennema & Frank (1992) and Peterson (1988). A research study to test the model is described, including a description of the coursework provided, and discussion of the methodology and data sources. Finally, the paper presents results from informal data that was collected, including class notes, teacher-made tests, and summaries written by the teachers describing assessment strategies that worked or did not work in their classes. These data, along with those from teacher observations and student reports, provide evidence that knowledge and use of alternative assessments did help mathematics teachers to change their teaching strategies to reflect approaches shown by research to result in higher order thinking.

A Theory of Classroom Assessment and Teacher Practice in Mathematics

Gerald Kulm, Texas A&M University

This study focused on the need to help teachers learn to improve the way they evaluate students' mathematics learning. The major objective was to develop assessment approaches that more accurately reflect teachers' own goals, the goals of the NCTM *Curriculum and Evaluation Standards* (1989), and other national recommendations. A more indirect, but important objective of the project was to study the impact of alternative assessment on classroom teaching practice.

Recent experience in American mathematics education seems to verify that the material tested is the material taught. The evidence from the National Assessment of Educational Progress (NAEP), for example, has shown that computational skills have been the focus for competency tests, spawning textbooks and instructional emphases aimed at developing these skills in students. Teachers have been legitimately concerned that if they "fight the system" and teach higher order thinking, their students would suffer on the computationally oriented tests that they are required to pass. Many educators believe that very little change will occur in mathematics curriculum and teaching without a concurrent change in testing, especially in state and national standardized tests that are used to assess and compare student, school, and district performances (Kulm, 1990).

Mathematics educators have called for new approaches to assessment and provided some directions for changes (Charles & Silver, 1989; Kulm, 1990; NCTM, 1989; Romberg, 1990). Promising work on developing new approaches to mathematics assessment has begun to appear at the national, state, and local level (CCSSO, 1989; NAEP, 1987;

Pandey, 1990; Stenmark, 1989; Strong, 1990). However, little research has been done on specific approaches to mathematics assessment and how they work with various student populations.

Most mathematics teachers believe that higher order thinking is important. In the Second International Mathematics Study, more than 60 percent of U.S. mathematics teachers listed their highest goal as "developing a systematic approach to solving problems and developing an awareness of the importance of mathematical everyday life" (Crosswhite et al., 1986). Student performance on the IMS and recent (NAEP) tests indicate, however, that the aspirations of teachers and the performance of their students are very different things. Apparently, teachers are unable to accomplish what they would like to be able to do.

Why don't mathematics teachers reach their own goals for teaching higher order thinking? There are several possibilities, including: (a) teachers really are trying to teach higher order thinking, but the students cannot learn, (b) teachers think that they are teaching higher order content but are actually teaching rote application of methods to solve special classes of word problems, (c) state and local tests demand that teachers do other things, or (d) teachers don't know how to evaluate student progress and achievement of higher order thinking. All of these explanations are probably true to some extent for many teachers. However, the last issue of how to evaluate higher order mathematical thinking would go a long ways toward overcoming other barriers. Successful teaching of anything, including higher order thinking in mathematics, is dependent upon the ability to determine the degree to which it has been learned. Valid and usable tests can provide an impetus for teaching higher order skills.

In this project, the goal was to bring instruction and assessment into closer alignment and interaction. This was made possible by helping teachers to develop the ability to assess the effects of teaching approaches that were designed to involve students in problem solving and thinking. Teachers were encouraged to broaden their repertoire of teaching strategies and to use alternative assessment strategies as a part of implementing these strategies. Work on developing alternative assessment plans contributed to bringing teaching and testing into agreement. Instead of being limited by traditional tests, teachers developed plans for assessment that fit within their own styles and approaches.

Teacher Change Model

Research on the effects of alternative assessment on the activities in teachers classrooms was a key objective of the project. We were interested to determine whether the use of alternative assessment had an effect on teachers' classroom instruction and on their students' attitudes toward mathematics. Fennema & Franke (1992) proposed a model which hypothesizes that teachers' knowledge develops in context, through the dynamic and interactive impact of knowledge of mathematics, pedagogical knowledge, and knowledge of learners' cognitions in mathematics. We propose that alternative assessments enhance teachers' knowledge in all three of these areas, but especially their knowledge of learners' cognitions and their knowledge about effective teaching. This knowledge enables teachers to transform their content knowledge into powerful pedagogical forms (Schulman, 1987).

In order to observe the outcomes of teachers' empowered pedagogical knowledge, we must look at those aspects of the classroom context which reflect powerful learning. A review of research on teaching by Peterson (1988) suggested that three primary classroom processes are essential for promoting the learning of higher-order thinking: (1) an emphasis on meaning and understanding, (2) encouragement of student autonomy and persistence, and (3) direct teaching of higher order thinking strategies. The interplay of these factors is depicted by Figure 1.

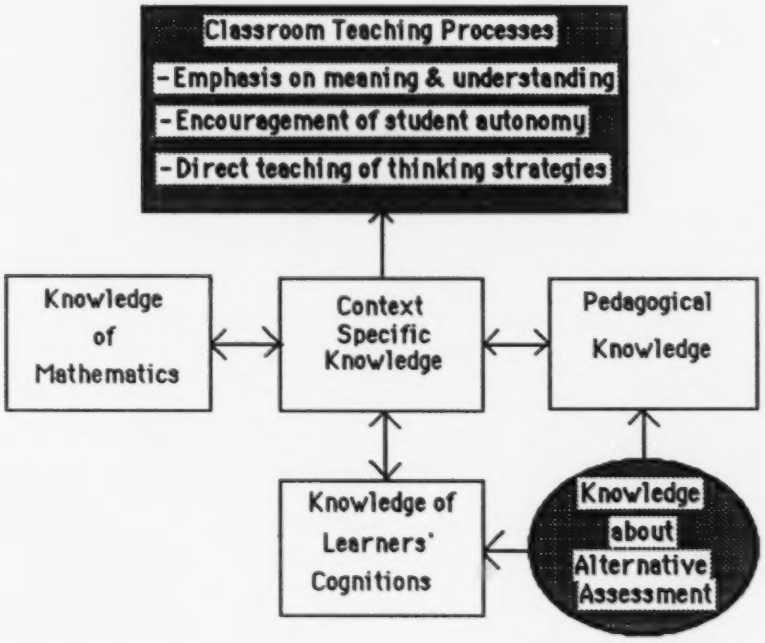
Classroom Teaching Processes
- Emphasis on meaning & understanding
- Encouragement of student autonomy
- Direct teaching of thinking strategies
Knowledge of Mathematics
Context Specific Knowledge
Pedagogical Knowledge
Knowledge of Learners' Cognitions
Knowledge about Alternative Assessment

Figure 1. Teachers' Knowledge: Impact of Alternative Assessment

In the proposed model, knowledge about alternative assessment strategies act to enrich teachers' knowledge of learners' cognitions. Teachers learn about their students' mathematical knowledge, understanding, and problem solving processes. They also learn how

students work on extended and complex problems, and how they communicate their work through oral, written, graphic, and other approaches. Finally, they learn how students do mathematics in individual and group situations. This enriched and in-depth knowledge about students has an impact on teachers' pedagogical knowledge. Teaching strategies that were dormant or not well developed become activated and intensified. More traditional teacher-centered approaches are used less often in light of assessments about their effectiveness in meeting students' cognitive needs. In some instances, knowledge of alternative assessment may also act upon and extend teachers' mathematical knowledge through work in developing tasks and evaluating students' mathematical performances.

Procedures

In order to test the proposed model, the project consisted of three coordinated components designed to help teachers plan and implement alternative assessment approaches: (1) Graduate course work on mathematics assessment to build knowledge about new assessment approaches and support implementation efforts, (2) Teacher development of assessment items and implementation of plans and strategies for student assessment, and (3) Development of assessment tasks and materials to support implementation efforts by teachers. Each of these components will be described in this chapter.

Selection of Participants: We tried to obtain a diverse group of teachers who worked in rural, suburban, and urban areas, who taught students of different backgrounds and ethnicities, and who had a wide range of abilities and experiences as teachers. Eighteen teachers, ranging from

fourth to tenth grades, from school districts in east central Texas were selected for participation in the project. The teachers were a very diverse and able group. Their experience ranged from 3 to 20 years of teaching. All of them had some graduate work, 7 of them had completed Master's degrees. There were 17 women and one man; four African Americans, the rest White.

Graduate Course Work: The teachers enrolled in and completed a 3-credit graduate course on mathematics assessment. The course will met twice a month, throughout the school year at Texas A&M. The outline for the course is shown in Table 1.

Table 1

Course Syllabus for EDCI 689 Innovative Mathematics Assessment

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EDCI 689. Innovative Mathematics Assessment. Credit 3 hours.

Course Description:

This course provides concepts, information, and strategies for designing multiple approaches to assessing mathematics performance, with special emphasis on helping teachers to develop comprehensive assessment plans, and providing support for classroom implementation.

Content Outline:

Class Session	Content
1	National and state mathematics assessment standards
2	Theories of mathematics learning and assessment
3	Types of mathematical learning to be assessed
4	Overview of new mathematics assessment strategies
5	Student mathematical products and outcomes

6	Portfolios of student mathematical performance
7	Assessment of minority and at-risk students
8	Assessment of individual student work
9	Assessment of cooperative learning groups
10	Development of specific assessment plans and methods
11	Assessment of student attitudes and beliefs
12	Holistic scoring rubrics and strategies
13	Assessment and grading
14	Summary and evaluation of strategies

Evaluation:

Text readings and assignments	25%
Assessment Plan	50%
Final Paper	25%

Textbooks:

Kulm, G. (1990). *Assessing higher order thinking in mathematics.* Washington, DC: American Association for the Advancement of Science.

Stenmark, J. K. (1989). *Assessment alternatives in mathematics.* Berkeley, CA: University of California.

Vermont State Board of Education. (1990). *Looking beyond the answer: Report of Vermont's mathematics portfolio assessment program.*

The focus of the course was on an analysis of current approaches to authentic mathematics assessment such as those outlined in the texts and assigned readings. In addition, special attention was given to assessment models developed by several state assessments such as California, Connecticut, and Vermont. As a required course project, each teacher

developed a plan for implementing alternative assessment in one of their mathematics classes or courses. The teachers also participated in developing and pilot testing a set of prototype assessment tasks. (See the section on the Alternative Assessment Question Bank for more information on this activity).

Assessment Plans and Implementation: Shortly after the beginning of the course, each teacher was asked to develop a tentative plan for implementing alternative assessment strategies. They were asked to identify one class in which to do this work. For elementary teachers, of course, this was their only class. The junior and senior high school teachers chose the class they felt most comfortable working with, one in which they thought the content was most compatible with alternative assessment, or one in which they felt students had the greatest need for change or motivation. There was a wide range of reasons for making these selections, and the teachers were not forced or directed to make any particular choice.

There was a great deal of early discussion about the types of changes in assessment to make and the schedule for doing so. The teachers were encouraged to make gradual changes and to involve their students, and possibly parents, in plans or discussions of how changes would be made. Teachers were also encouraged to try and work toward using alternative assessment for a majority of testing and evaluation in the selected class by the end of the year.

During the course, the teachers implemented their assessment plans and shared experiences on what worked in their classes. Much of the discussion at class meetings was devoted not only to providing information

on assessment, but to encouraging the teachers to share and clarify approaches that they were trying in their classes. Among the issues that arose consistently were:

- approaches to assigning grades
- the use of scoring protocols on open ended items and problems
- integration of writing, such as journals, into the evaluation process
- the use of timed tests
- the assessment of group vs individual work during cooperative learning activities
- the attitudes of students in accepting new assessment approaches

As classroom implementation took place, it became clear that much of the discussion about procedures and strategies focused on teaching as much as on assessment. Many of the teachers' plans for implementing alternative assessment approaches were closely tied to strategies for using problem solving or communications activities as a regular part of instruction. For example, several teachers implemented a "problem of the week or problem of the day" approach to help students develop higher order thinking abilities. Some of these teachers used the problems at times as cooperative group activities; others asked students to select their best problem for presentation or evaluation; others asked students to choose a problem to include in a portfolio.

Several teachers implemented group and project assignments, working with hands-on materials or calculators. Although many of the participants were comfortable with these kinds of strategies, the project and the input from fellow participants encouraged a few teachers to try these methods either for the first time or to make them a regular part of their instruction.

Data Collection

Classroom Observations: A classroom observation instrument was developed, focusing on the three processes essential for promoting the learning of higher-order thinking. Special attention was given to characterizing teaching approaches that reflect non-traditional strategies such as problem-based instruction, small group and other student-centered work, and attention to student learning as opposed to "covering" mathematics content. The following paragraphs describe the general procedures used to collect observation data.

An experienced doctoral student in mathematics education observed the teachers, using the observation instrument to rate the extent to which the teacher exhibited each of the behaviors. An initial set of observations was done early in the project, prior to teachers' implementation of their assessment strategies. This first observation served to establish baseline data on teaching strategies. During the school year, each of the teachers was observed two more times, once near the middle of the project, and once at the end of the school year. These observations provided data that reflected changes in teaching approaches during the year.

In addition to collecting teacher behavior ratings from the observer, each teacher also rated themselves on each of the observation items, following the lesson. These ratings were discussed with the teacher as part of the post-lesson interview session. This self-rating served to focus teachers' attention on the types of teaching strategies that are identified as ones that enhance higher-order thinking skills in students. The self-rating data also provided a source for validating the observation ratings.

Finally, each observation was video-taped. Although this video-taping was not a part of the original proposal, we decided that it would provide additional valuable data. The complete analyses of the video-tapes are not reported here, but will become a focus of the dissertation by the doctoral student. We did use the video-tapes as a source for doing a reliability analysis of the observation ratings.

Journals, Classroom Tests, and Quizzes: Each teacher kept a journal of their classroom work and activities, focusing on assessment implementation. The journals were handed in at each class meeting. There were no specific guidelines for the journals, but teachers were encouraged to record their approaches to assessment, how they worked, reflections on special areas of interest, good ideas, special classroom episodes, or any other information that would reveal the progress of implementing their assessment plans. Many of the journals described the types of assignments and activities that were used to assess student learning, and the reactions of both themselves and their students as they made these changes.

Samples of classroom tests used by the teachers were collected at the end of the project. These items were intended to provide indicators of how extensively the teachers actually implemented the innovative assessment approaches. Of special interest was the extent to which the new assessment approaches begin to permeate the day-to-day classroom quizzes and tests, and whether the classroom tests show variety in their format and setting.

Student Questionnaires: Student questionnaires provided another indicator of whether teachers changed their teaching and assessment approaches. On the same schedule as the observations at the beginning of the year, the middle, and again near the end, students were given a 25-item

questionnaire. The first ten items provided an indication of whether the innovative testing approaches had an impact on the way students viewed mathematics. The last 15 questions provided indicators, from the students' point of view, whether teachers' classroom practices changed as a result of the assessment work.

Summary of Teacher Outcomes

In this project, we have made some significant progress in developing teachers' knowledge of how to assess problem solving and other types of higher order thinking. This knowledge appears to provide teachers with the freedom to choose and implement instructional activities which enhance higher order thinking. These teachers have begun to find ways in which they can achieve their own and their school's goals of teaching for conceptual understanding, problem solving and reasoning in mathematics.

We found that when teachers used alternative approaches to assessment, they also changed their teaching. Teachers increased their use of strategies that have been found by research to promote students' higher order thinking. They did activities that enhanced meaning and understanding, developed student autonomy and independence, and helped students learn problem solving strategies. Students' attitudes toward math improved. Students reported being more involved in group work, using calculators, making up their own problems, and other activities which reflect active rather than passive mathematics learning.

Teachers provided feedback at the end of the project, outlining some of the abilities, knowledge, and skills that they had developed. They reported learning a variety of approaches for helping students to learn

basic mathematical facts and skills. The teachers said that they were more able to:

- foresee students' problems in computational skills and emphasize steps to overcome these skill areas
- develop a system of homework and quizzes to give an accurate description of their abilities
- give different forms of assessment, having students show and explain their work
- ask probing questions to encourage students to arrive at the correct answer
- use questioning techniques which can help to recognize students' errors
- use multiple approaches in assessing students' knowledge and skills
- develop and use rubrics to score student work
- feel comfortable in allowing students to use models and manipulatives

Teachers also developed knowledge of strategies for teaching mathematical reasoning and problem solving. They reported feeling more capable in:

- selecting open-ended problems that meet the level of experience of students, building problem difficulty systematically
- using open ended problems to evaluate problem solving ability
- looking for alternative methods and approaches
- spending time discussing problem solving strategies
- helping children not afraid to be afraid of thinking

- requiring students to engage daily in problem solving and requiring them to demonstrate and communicate understandings in mathematics - orally and in writing
- focusing on process rather than simply on an answer
- being willing to try new ideas
- using questioning techniques and encouraging the students to expand on answers and ideas
- being able to follow the thought processes of all students
- working with students one on one

Although most of the teachers indicated that they still had much to learn about alternative approaches to assessment, they felt confident in trying further ideas, and expressed the desire to implement their ideas in the coming year. Many of them felt they could be even more successful if they were to implement these strategies at the beginning of the school year.

Information about new approaches to mathematics assessment at the classroom level is critical for further progress in reforming mathematics education. If student performance on national, state, and local assessments is to meet the expectations of new standards, instruction and assessment must be closely aligned. This study provided evidence that inservice work on alternative assessment can pay dividends in helping mathematics teachers use approaches which enhance higher order thinking processes.

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